A Public Health Project

DDT and DDE Transmission Through Breast Milk: Yakima River Basin

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Office of Environmental Health Assessment Services

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Appendices

DDT and DDE Transmission Through Breast Milk: Yakima River Basin

DDT and one of its primary environmental and biological degradation products, DDE, have been detected in sediments and fish from the Yakima River and its tributaries and drainages. The concentrations of these organochlorines in fish are among the highest in the United States. Fishing is a popular activity in this area and many individuals catch bottom-feeding fish species (i.e. mountain whitefish and large-scale sucker) that may contain high levels of these compounds.

To properly address the possible effects associated with consumption of contaminated fish from this area, a public health project was initiated. Outreach activities were initiated which consisted of education and a brochure which provided information on DDT and DDE and recommendations on the consumption of fish from the Yakima River area. This was followed by three major phases of the project, which are described below.

Phase I

Determining of a Tolerable Daily Intake of DDT for Consumers of DDT Contaminated Fish from the Lower Yakima River. An assessment was conducted to evaluate the public health significance of eating contaminated fish from the Yakima River (Appendix A). This was accomplished by establishing a daily intake level of DDT and DDE for the population of greatest concern and comparing this level to a tolerable daily intake (TDI) that was developed as part of the assessment. The most sensitive and highly exposed group was determined to be breastfeeding infants. By protecting this population, all other populations are protected as well.

DDT and DDE are lipophilic organochlorines which are secreted in breast milk. Since DDT and DDE from a mother's diet concentrates in breast milk, an estimate of DDT and DDE concentrations in breast milk was developed based on the mother's consumption of contaminated fish. Infant daily intakes of DDT and DDE, based on the mother's DDT and DDE-breast milk levels, were compared to a recommended tolerable daily intake to determine the need for action. Pertinent epidemiological and toxicological data used to develop the tolerable daily intake, which is based on a developmental neurotoxic endpoint, were reviewed. Results indicated that mothers who frequently consume Yakima River bottom-feeding fish could have breast milk DDT and DDE concentrations sufficiently high to expose their infants to levels above the tolerable daily intake.

Since results of this phase suggested that infants could possibly be overexposed to DDT and DDE through breast milk, a study was initiated in the Yakima River Valley to determine if such a population existed.

Phase II

Determining Infant Population Size in the Yakima River Valley Exposed to DDT and DDE through Breast Milk. A large number of minorities, mostly Hispanic, are employed as agricultural laborers in the Lower Yakima Valley. The Hispanic population comprises 24.4 percent of Yakima County and up to 80 percent of lower valley towns such as Mabton. Due to undercounting of Hispanics in the 1990 census and influxes of migrant workers during the fruit picking season, these figures most likely underestimate the true proportion of Hispanics in this area. Low income populations of migrant seasonal workers are among the agricultural work force which may rely on Yakima River fish as a primary source of protein. Women who regularly eat contaminated fish from the Yakima River may be transmitting higher than tolerable doses of DDT and DDE to their infants through breast milk.

Previous studies in other geographical areas have found that nursing women who eat contaminated fish have DDE levels 14 percent higher than nursing women who did not consume such fish. A study was conducted to define, in terms of size and demographics, the infant population exposed to DDT and DDE in order to assess the magnitude of the problem (Appendix B). The most exposed population was determined to be the low-income Hispanic community which is difficult to access. Results indicate that at least twenty-four infants in this geographical area could be exposed annually to elevated DDT and DDE breast milk levels. Due to persistence DDTs in the environment, hundreds of infants could be exposed to deleterious levels in the future.

Results of this study indicated that there was an infant population requiring protection; therefore a study was initiated to determine actual breast milk contamination and assess the impact of fish consumption on DDT and DDE breast milk concentrations.

Phase III

The Effect of Fish Consumption on DDT and DDE Levels in Breast Milk Among Hispanic Immigrants. Mothers who frequently consume Yakima River bottom-feeding fish could have breast milk DDT and DDE concentrations sufficiently high to expose their infants to potentially deleterious levels of these compounds. A study was conducted to determine actual levels of DDT and DDE in breast milk of mothers residing in the Yakima River basin, to assess the relative impact of fish consumption on the total DDT and DDE body burden, and to determine if total DDT and DDE levels received by breastfeeding infants were elevated to potentially deleterious levels (Appendix C). Results indicated that fish consumption did not significantly increase DDT and DDE breast milk concentrations. However, subjects born in Mexico had elevated levels of DDT and DDE in breast milk compared to levels found in U.S. born subjects. With the exception of two Mexico-born women, infant exposure levels for both groups were below the previously established tolerable daily intake.

The benefits of breast milk are well understood, and the results presented in this study should not dissuade health care professionals from strongly recommending breastfeeding for all women including those in this geographical area. However, the elevated levels in breast milk observed in the Mexico-born immigrants does raise concerns about this population in the United States. Any population potentially affected through DDT and DDE exposure should be monitored to ensure that infant exposure levels are below the TDI and that levels decrease as exposure is removed. Also, the involvement of DDT as an endogenous estrogen in causing neurological and developmental effects should be vigorously pursued. While further research results are forthcoming, Lactation Clinics and programs such as WIC and Maternal and Child Health outreach are a primary source for public health intervention by providing education and information on the benefits of breastfeeding, and the possible health consequences that could occur from overexposure to compounds like DDT and DDE. By coordinating efforts with these programs, populations of greatest concern can be reached and educated in regard to improved dietary practices and the benefits of breastfeeding.

APPENDIX A

Determination of a Tolerable Daily Intake of DDT for Consumers of DDT Contaminated Fish from the Lower Yakima River

Determination of a Tolerable Daily Intake of DDT for Consumers of DDT Contaminated Fish From the Lower Yakima River

ABSTRACT

DDT, DDE and DDD have been detected at elevated concentrations in sediments and fish of the Yakima River, its tributaries and drainages. An assessment was conducted to evaluate the public health significance of eating fish from the river. This was accomplished by establishing a daily intake level of DDT for the population of greatest concern, and comparing this level to a tolerable daily intake. The most sensitive and highly exposed group was determined to be breast-feeding infants. Infant daily intakes of DDT, based on estimated mother's DDT-breast milk levels, were compared to a recommended tolerable daily intake. Results indicate that mothers who frequently consume Yakima River bottom-feeding fish could have breast milk DDT concentrations sufficiently high to expose their infants to levels above the tolerable daily intake.

INTRODUCTION

The Yakima River runs through a major agricultural area as it flows through central Washington on its way to its confluence with the Columbia River near Richland, WA. For decades, crops in this region were treated with DDT, which was used extensively as an insecticide until it was banned in the early 1970's. The United States Geological Survey (U.S.G.S.) collected and analyzed fish and shellfish samples from the Yakima River, its tributaries and adjoining agricultural drainage areas from 1989 to 1991 as part of their National Water-Quality Assessment Program.(1) High levels of the pesticide DDT and its two primary degradation products, DDE and DDD were found in bottom-feeding fish species. The extent of fish contamination is such that the median concentration for DDT and DDE in largescale sucker (1.63 mg/kg) from the Yakima River samples was higher than in all but a few of the freshwater fish samples collected in the U. S. during 1984 and 1985. (2)

Since fish species containing DDT and DDE are caught along the Yakima River,(3) the public health implications of consuming these fish were assessed using the following method 1) a tolerable daily intake (TDI) of DDT and DDE was developed for individuals most sensitive to the effects of these compounds, i.e., infants, 2) a daily intake of DDT and DDE was estimated for breast-feeding infants of mothers who may rely on Yakima River bottom-feeding fish as their primary source of dietary protein, i.e., estimated for subsistence consumers, and 3) these daily intake estimates of DDT and DDE for infants were compared to the TDI to determine if consumption of Yakima River bottom-feeding fish could be a health concern for this population.

METHODS

U.S.G.S. DATA

U.S.G.S. collected fish and shellfish samples from 32 sampling stations along the Yakima River, its tributaries and adjoining agricultural drainages. Tissue samples were analyzed for o,p- and p,p-isomers of DDT, DDE, and DDD with a detection limit of 0.01 mg/kg (wet weight) reported for each isomer. Only data for largescale sucker and mountain whitefish were used in this assessment because these data make up the majority (72%) of the composite samples and data from the remaining bottom-feeding fish species are consistent with the largescale sucker and mountain whitefish data set.[1] DDT and DDE fish data were used to determine the ratio of fillet to whole body concentrations of the sum of both o,p- and p,p-isomers of DDT and DDE [Σ(DDT and DDE)] for both species (Table 1). (For reasons discussed below, the DDD concentrations were excluded from further analyses.) Mean fillet to whole body Σ(DDT and DDE) ratios were determined to be 0.23 and 0.56 for largescale sucker and mountain whitefish, respectively. The product of whole body Σ(DDT and DDE) concentrations and the appropriate species fillet to whole body Σ(DDT and DDE) ratio approximates Σ(DDT and DDE) concentration in fillet tissues. In our exposure assessment, these ratios were used to estimate fillet concentrations from whole body concentrations for all remaining sites where empirical fillet data were not available, i.e. for 1989 and 1990 samples (Table 1).

ESTIMATED DAILY INTAKES

In order to assess potential health impacts from eating Yakima River bottom-feeding fish, daily intakes of DDT and DDE were estimated for nursing infants of mothers consuming subsistence quantities of contaminated fish. Breast milk is the primary exposure route for this population. To address this exposure pathway, it was necessary to derive estimates for three parameters; mother's daily intake of DDT and DDE from eating contaminated fish, the concentration of DDT in breast milk resulting from this intake, and the infant's daily intake of DDT through consumption of contaminated breast milk (Figure 1). The derivations of these three parameters are presented in the following sections.

Daily Intake Estimates For Mothers

The amount of DDT and DDE in breast milk depends on the mother's body burden which is based on her dietary intake level. Since DDT is lipophilic, an individual's body burden is a function of the amount of DDT stored in adipose. Experiments with volunteers indicate that subjects ingesting various quantities of DDT for prolonged periods attain an equilibrium level of DDT in lipid at 18 to 22 months after initial exposure.[4] Assuming that DDT concentrations in lipid reach equilibrium in the general public, as observed in human volunteers who consumed larger quantities, a body burden in the general public would also be attained from a daily intake level after approximately two years. Once a body burden is attained and maintained by a constant daily intake, the breast milk DDT levels are reflective of not only the DDT body burden, but also the DDT daily intake levels.

To accurately determine mother's daily intake (MDI), data on fish consumption rates, fish contaminant concentrations, and the relative quantities of species of fish consumed should be obtained for the population of concern. Data for some of these variables were not available for the population along the Yakima River and therefore values from similar studies were used. Values for these variables were chosen so as to include people who may rely on Yakima River bottom-feeding fish as their primary source of dietary protein, i.e., dietary intakes were estimated for subsistence consumers. A MDI was determined for each of the two fish species using the following equation:

$$MDI_i = (FC_i \times FWB_i \times MS \times MF) / BW$$

where:

MDI = Mother's daily intake (mg/kg-day)

i = Species; either largescale sucker or mountain whitefish

FC = Fish concentration: median concentration, in mg/kg wet weight, of Σ(DDT+DDE) in whole body fish (Table I) from all locations sampled (0.84 mg/kg for whitefish & 1.63 mg/kg for sucker)

FWB = Mean fillet to whole body DDT + DDE ratio; 0.23 for largescale sucker and 0.56 for mountain whitefish (see text)

MS = Meal size (0.23 kg/meal)[5]

MF = Meal frequency (16 meals/month ≈ 0.5 meals/day)[5]

BW = Bodyweight for adult female (60 kg)[6]

The median fish concentration value from all samples taken at the various sampling stations for each species was used to determine the intake values (Table 1). This produces an MDI of 9.0×10^{-4} and 7.2×10^{-4} mg/kg-day for mountain whitefish and largescale sucker, respectively. Until data on quantity and type of fish consumed are obtained for the population in the Yakima River basin, equal consumption rates for both species are being considered the norm for the population. This results in an average MDI of 8.1×10^{-4} mg/kg-day. This MDI is used to establish daily intakes for infants from breast milk of mothers who have attained a body burden and who are maintaining it through consumption of contaminated fish.

DDD concentrations were not used to establish the MDI since DDD represented on average only 13% of the total DDT, DDE and DDD amount detected in each sample collected. Also, since our sensitive population is infants and a TDI is being established based on exposure from breast milk, DDD was considered to be of little significance since it is the most readily excreted of the three compounds and comparatively little or no DDD has been found in breast milk of individuals tested over the last two decades.[4,7-11]

Breast Milk Lipid DDT Concentrations

The infant daily intake of DDT and DDE depends on the concentration of these compounds in the breast milk of the mother. Concentrations of DDT and DDE in breast milk of mothers in the Lower Yakima River basin are not known. Additionally, the relationship between dietary intake of DDT and DDE and resulting breast milk concentrations has not been determined through human studies. In the absence of these data, two approaches for determining breast milk lipid concentrations (BMLC) for the population of concern were used. These two approaches, which relied on different available human data sets resulted in similar infant daily intakes (IDI).

Estimating BMLC - Method 1

This method uses an equation developed from human studies which describes adipose DDT concentrations as a function of dietary DDT intake. A reported relationship between adipose DDT concentrations and breast milk lipid DDT concentrations was used to estimate breast milk DDT concentration.[12]

Durham and co-workers[13] identified a relationship between daily intake of DDT and body fat concentrations. Adipose concentrations and daily intakes of DDT measured in previous studies were found to follow a linear algorithm.[13] The algorithm derived from the data is ln BF = 0.7 ln I + 3 where BF is the storage in body fat in mg/kg and I is the mean intake level in mg/man-day.[13]

Wolff indicated that for PCBs and related organochlorines, the ratios of concentrations of such compounds in body fat and breast milk fat approached one. Thus, using the relationship between DDT in adipose and intake of DDT established by Durham, and relying on a 1:1 ratio of DDT concentrations in adipose to breast milk lipid concentrations, a breast milk lipid concentration of DDT can be calculated as follows:

$$\ln BMLC = 0.7 \ln (MDI \times BW) + 3$$

Using the MDI of 8.1×10^{-4} mg/kg-day, the BMLC is 2.4 mg/kg.

There are uncertainties associated with this approach. The relationship between intake and adipose levels was derived from data from multiple studies. Differences in methodologies and results among the studies are not considered. Additionally, by determining a relationship based on mean levels, differences in sample size of study group and variance within study groups are not addressed.

To verify and determine the relevance of Method 1 for establishing an IDI value based on maternal intake, another approach was taken to estimate breast milk DDT concentration (Method 2).

Estimating BMLC - Method 2

This method compares the mean total DDT intake for the U.S. population from the 1960's and 1970's to breast milk concentrations from the same time period. Dietary intake of total DDT for the general U.S. population in 1965 and 1970 has been estimated by the EPA to be approximately 1×10^{-3} and 4×10^{-4} mg/kg-day, respectively.[12] The calculated intake value (8.1×10^{-4} mg/kg-day) for mothers consuming whitefish and sucker lies squarely between the EPA intake estimates.

Information gathered in the general population from studies initiated between 1965 and 1971 on total DDT breast milk levels provided an estimate of breast milk concentrations for the population in the Yakima River basin who have similar estimated dietary total DDT intakes.[14-17] The study by Savage et al. which was initiated in 1971, was included in this data set since Kutz et al. has suggested that mean lipid-adjusted total DDT values remained fairly constant between 1970 and 1971. Assuming that both the general population in the 1960's and the population of concern along the Yakima River have been exposed to DDT levels approximating their respective estimated daily intakes for two or more years, a steady state equilibrium level of DDT in lipid will have been established in both population sets. Once this equilibrium level is established, a body burden is maintained from the daily intake level. As a result, this same intake level can be associated with a certain breast milk DDT level. Breast milk total DDT concentrations on a whole milk basis from the studies initiated between 1965 and 1971 ranged from 0.078 to 0.17 mg/kg. Since breast milk is approximately 4% lipid, these values correspond to 1.95 and 4.25 mg/kg of lipid.[18] The value of 3.15 mg/kg, which represents the median of the study values was used as the BMLC for individuals having similar dietary intakes in the Lower Yakima Valley.[17]

Daily Intake Estimates For Infants

With a derived MDI and two breast milk lipid concentrations, infant daily intakes of DDT and DDE were determined using the following equation:

$$IDI = (BMLC_{(MDI)} \times MC \times PMF) / BW$$

where:

IDI = Infant daily intake (mg/kg-day) from consumption of breast milk.

BMLC = Breast milk lipid concentration of DDT and DDE (mg/kg) as a function of the mother's daily intake (MDI).

MC = Consumption of breast milk (1 kg/day)[18]

PMF = Percent milk fat in breast milk (kg breast milk lipid/kg whole breast milk) (4%)[18]

BW = Bodyweight for nursing infant (5 kg, 50th percentile for a 2 month old baby)[19]

With the BMLC value derived from Method 1 (2.4 mg/kg) the resulting IDI is 2.0×10^{-2} mg/kg-day. The BMLC obtained from Method 2 (3.15 mg/kg) resulted in an IDI of 2.5×10^{-2} mg/kg-day.

TOLERABLE DAILY INTAKE

A Tolerable Daily Intake (TDI) was developed for this study based on a review of the epidemiological and toxicological literature. Special attention was given to studies which evaluated effects at low level exposures, i.e. provided information on sensitive toxic endpoints. Although there is a large database on DDT human toxicity, most of the work focuses on high level exposures and on endpoints which may not be particularly sensitive in light of current research. As a result, animal studies assessing sensitive endpoints were used to supplement the results of human studies in developing a TDI. The following is a brief overview of several of the studies which guided the selection of a TDI and represents a portion of the DDT review which was conducted for this study.

There are large amounts of human epidemiological and human control study data which address DDT, DDD and DDE exposures. One set of occupational studies attempted to correlate effects with estimated levels of DDT exposure.[20,21] These two studies by Laws and co-workers estimated daily intake levels for workers chronically exposed to DDT for an average of approximately 20 years. These studies were completed on the same worker population; 35 workers in the initial study and 31 workers in the follow-up study. Exposure levels ranging from 0.05-0.26 mg/kg-day were estimated for this worker population. Laws and co-workers used two separate methods for estimating exposure; DDT concentration in fat and DDA excretion in urine. Their two methods gave similar results thereby supporting the accuracy of the intake estimates. These studies found no evidence of hepatic enlargement, dysfunction, or toxicity, as assessed by correlating DDT serum levels and liver function tests.

In the absence of complete human data for particular sensitive toxic endpoints, animal data using relatively low doses of DDT were also considered in developing a TDI. Acute exposure DDT studies have shown that DDT interferes with neural function. Observations in adult rodents indicate that acetylcholine in the brain was elevated shortly after intracarotid administration of DDT but showed a decrease in the cerebral cortex hours after oral exposure.[22-25] Signs of severe poisoning such as hyperthermia and tremor were also observed in these animals. DDT exposed rats have been shown to have increased levels of biogenic amine metabolites and excitatory amino acids.[26,27] Also, DDT has been shown to increase the closure time of sodium channels which results in prolonged depolarization and repetitive firing of the neuron.[26,28-30]

Teratology studies by Eriksson and co-workers, have investigated neurological and developmental endpoints in mice.[31-33] In these experiments, DDT (0.5 mg/kg-day) was administered to neonatal mice. The mice were subjected to several behavioral tests during adulthood which monitored locomotion, rearing and activity. In the adult mice receiving DDT at age ten days, Eriksson and co-workers observed impairment of brain function which was measured in several ways. A significant increase in spontaneous motor behavior, including a hyperactive condition, was observed. The observed teratogenic effects are convincing since psychoactive agents, therapeutic drugs or other compounds, are likely to cause permanent injury to the central nervous system if exposure occurs during development.[34-36] As stated, DDT is psychoactive since it causes neurological symptoms as well as changes in neurotransmitter levels. Further, the effects are credible since hyperactivity, as well as alteration in transmitter systems, observed by Eriksson and co-workers are characteristic of many kinds of brain damage.[31-33] Also, the observed effects of neonatal DDT exposure are similar to those of several insecticides.[37,38] Although work is still required to elicit the nature of low-dose DDT damage to the central nervous system in neonates, the results of these experiments by Eriksson and co-workers suggest that: 1. the neonatal period of brain development may be similar to other perinatal periods in which the brain is susceptible to xenobiotic compounds. and 2. susceptibility to damage by DDT and similar acting compounds may be greatest during the height of rapid brain growth and during the rapid development of muscarinic acetyl-choline receptors in the cerebral cortex.[31-33,39]

Though a direct comparison between ten-day old mice and ten-day old humans cannot be made, the sequence of events of brain development between humans and rodents is quite similar.[34,40] That is, nerve production, myelin formation, receptor development, etc. are events that occur in the same order in humans and rodents.[40] At day ten, mice are in their last stages of neuron production for the cerebellum and hippocampus.[41] Anti-mitotic drugs would be much more toxic if given earlier in development when more neurons are being produced.[35,42] However, the first two weeks of postnatal life in the rodent are a period of rapid development of synaptic connections, transmitter systems, and myelination. Many teratogens interfere with some or all of these events, and thus cause permanent injury when exposure occurs at this stage of brain development. For example, lead, cadmium and organotins can injure the brain at this stage, as can hypothyroidism. [43] The applicability of present research results to the human situation will continue to become clearer as future findings delineate effects at developmental time points when mice are more sensitive, and when the development of rodent and human neurosystems are similar.

Although it is always difficult to form health decisions based on only a few studies, the information available provides two possibilities for extrapolation to humans for developing a TDI. One option is to use the studies by Laws et al. to define a human no-effect level of 0.26 mg/kg-day divided by ten to account for sensitive human populations.[20,21] The other option is to use an acute dose to a rodent of 0.5 mg/kg-day from the studies by Eriksson and co-workers and divide it by 100 to account for inter-and intra-species differences.[31,32]

We recommend that the more protective value of 0.5 mg/kg-day (with an order of magnitude lowering in the value to control for sensitive populations and another for intraspecies differences), be used as a basis for a TDI. This results in a TDI of 0.005 mg/kg-day which could be applied to a similar sensitive population such as nursing infants. An additional factor of 10 was not applied to account for using an observed effect level as is customarily done since these data are limited in both scope and size, and little supporting data pertaining to these endpoints exists. Also, the endpoints from the epidemiological studies, though not as sensitive as desired, do not presently support a more stringent TDI. Therefore a TDI of 0.005 (5×10^{-3}) mg/kg-day is recommended as the most satisfactory value with which to protect public health.

RESULTS

The two different methods used to determine IDIs for DDT and DDE from ingestion of contaminated Yakima River bottom-feeding fish resulted in similar results. This suggests that intake levels can be derived and supported using different data sets. The resulting IDIs, 2×10^{-2} and 2.5×10^{-2} mg/kg-day, exceeded the TDI of 5×10^{-3} mg/kg-day for DDT and DDE (Table 2). This indicates that the population eating subsistence quantities of fish from this water body may be exposing their new born infants to unsafe levels of these compounds. Based on this result, information about the contamination, and recommendations for ways to reduce exposure have been provided to people living in the area. Recently, a follow-up study has been initiated in this area to examine actual breast milk concentrations of DDE and DDT in lactating women to ascertain if eating the contaminated fish is a major source of exposure for this population and to determine what further steps can be taken to better protect the health of this population.

DISCUSSION

Several agencies and organizations have existing guidelines for daily DDT intakes or recommended maximum DDT levels in fish tissue, [44-46] but these existing guidelines were not used in this assessment because they are not based on recent studies which evaluate sensitive endpoints in human and animal populations. Additionally, existing toxicity values may incorporate policy related considerations into the derivation of numeric guidelines. Such considerations tend to reflect the regulatory mandate of the agency for which the guideline was developed but may not apply to population-specific public health circumstances. For example, toxicity values (slope factors and RfDs) developed by the EPA are very useful as screening levels but are generally not relied upon for forming health decisions because of the methodology used to derive them, and the assumptions incorporated into them for regulatory purposes. The approach presented allows for the review of available toxicity data and the development of a toxicity evaluation which is protective and considers multiple public health concerns.

In deriving the IDI, *in utero* exposure and duration of breast feeding were not addressed. The addition of these two variables would encompass total infant exposure. *In utero* exposure may be of little significance since Wolff has suggested that transplacental migration of PCBs and other related non-polar compounds, such as DDT, is potentially small compared to the quantity obtained through breast milk. Various studies have shown that changes in total DDT breast milk levels occur during lactation.[9,47-49] DDT and metabolite levels decrease in breast milk as the duration of breast feeding increases.[9] Since frequency of breast feeding decreases with infant age, the highest level of exposure and greatest intake per unit body mass occurs during the first few months of feeding.[9] Although extent and duration of breast feeding is known in humans, and these parameters could have been included in determining the IDI, their relationship to the sensitive developmental neurotoxic endpoint used to determine the TDI can only be clarified once more is known about the endpoint itself and how this endpoint in rodents relates to humans.

The analyses presented suggests that this population, as well as others in and outside of this country that rely on fish as a major source of dietary protein, could be exposed to DDT at sufficient concentrations to produce deleterious effects. The analyses also highlights the need for information to evaluate exposure to nonpolar organic chemicals through breast milk. Breast milk is often cited as an exposure route of concern for lipophilic chemicals yet there are few models with which to assess this exposure route quantitatively. Exposure through breast milk is especially important when assessing populations exposed to pesticides through multiple routes such as farmworkers or populations world-wide where DDT use and environmental contamination are more widespread.

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Table 1. Concentrations of DDT and DDE in fish used to estimate daily intake levels.[(1)]

Fish Species	Sampling Station[a]	Whole Fish Σ(DDT+DDE)[b] (mg/kg)	Fillet Σ(DDT+DDE) (mg/kg) (predicted from whole fish concentrations[c] except where noted)
Mountain Whitefish	4	0.10	0.06
	4	0.10	0.06
	14	0.20	0.11
	22	0.68	0.38
	24	0.98	0.55
	40	1.11	0.62
	43	0.12	0.07
	51	1.50	0.84
	51	1.70	0.95
	51*	0.84±0.26*	0.47±0.31*
Largescale Sucker	13	0.05	0.01
	14	0.28	0.06
	22	0.48	0.11
	24	0.69	0.16
	26	0.30	0.07
	32	0.50	0.12
	32	0.73	0.17
	36	1.76	0.40
	38	1.15	0.26
	39	1.63	0.37
	40	2.08	0.48
	46	4.37	1.01
	47	2.87	0.66
	47	2.99	0.69
	51	2.04	0.47
	51	2.22	0.51
	51	2.45	0.56
	51*	0.92±0.37*	0.21±0.17*

a Samples are composites of 10 whole fish except at sites 24, 26 and 36 where number of fish per composite were 8, 4 and 9, respectively. Composite samples were collected in 1989 and 1990.

b Σ(DDT+DDE) is sum of concentrations (wet weight) of both o,p- and p,p- isomers of detected data only (detection limit of 0.01 mg/kg reported for both isomers of DDT and DDE).

c Predicted fillet Σ(DDT+DDE) concentration is product of whole body Σ(DDT+DDE) concentration and species specific fillet to whole body Σ(DDT+DDE) ratio; ratio for sucker is 0.23, ratio for whitefish is 0.56 (see text).

* Individual whole body and individual fillet samples collected in 1991 at station 51 only; concentration is mean (± standard deviation) of 10 samples. Data for whole body and fillet samples are from the same 10 fish.

Table 2. Summary of Exposure Estimates Compared to the Tolerable Daily Intake for DDT and DDE.

Mother's Daily Intake (MDI)	Breast Milk Lipid Concentration (BMLC)	Infant's Daily Intake (IDI)	Tolerable Daily Intake (TDI)
8.1×10^{-4} mg/kg-day[a]	Method 1: 2.4 mg/kg	Method 1: 2×10^{-2} mg/kg-day	5×10^{-3} mg/kg-day
	Method 2: 3.2 mg/kg	Method 2: 2.5×10^{-2} mg/kg-day	

a Mean of MDI's calculated for mountain whitefish and largescale sucker.

APPENDIX B

Determining Infant Population Size in the Yakima River Valley Exposed to DDT and DDE through Breast Milk

Determining Infant Population Size in the Yakima River Valley Exposed to DDT and DDE through Breast Milk

Abstract

Fish collected from the Yakima River were found to have DDT/DDE levels among the highest recorded in the United States. Mothers who frequently consume Yakima River bottom-feeding fish could have breast milk DDT/DDE concentrations sufficiently high to expose their infants to potentially deleterious levels. A study was conducted to define, in terms of size and demographics, the infant population exposed in order to assess the problem's magnitude. The most exposed population was determined to be the difficult to access low-income Hispanic community. At least twenty-four infants could be exposed annually to elevated DDT/DDE breast milk levels. This study provided an example of successful community networking and innovative identification of a hard-to-reach population. Due to DDT's persistence in the environment, hundreds of infants could be exposed to deleterious levels in the future.

Introduction

1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane (DDT) and its metabolite 1,1-dichloro-2,2-bis(p-chlorophenyl)-ethylene (DDE) are lipophilic organochlorine pesticides which can be concentrated in humans. Although use of DDT has been banned in many countries, persistence in the environment of DDT and DDE (DDT/DDE) has resulted in continued detection of these compounds in breast milk of women. Little is known about short-term effects of DDT/DDE on children, or the effect, in later life, of neonatal exposure to these compounds. Nonetheless epidemiological investigations have documented hyporeflexia in infants whose organochlorine measurements were high.[1] Teratological studies using low doses of DDT have been associated with developmental and neurological impairment in neonatal mice.[2-5]

The Yakima River basin of eastern Washington is a major production site for fruits and vegetables with the river an indispensable water source for irrigation of the naturally arid lands. Yakima County is ethnically diverse, with 24.4% of the population classifying themselves as Hispanic and 4% as Native Americans.[6] Prior to its ban in 1972, DDT was sprayed throughout the area for decades, due to its effectiveness as an insecticide.

Between 1989 and 1991, the United States Geological Survey collected sediment and fish samples from the Yakima River basin.[7] Large-scale sucker and mountain whitefish were found to have DDT/DDE levels among the highest recorded in the United States. Previous results indicated that mothers who frequently consumed Yakima River bottom-feeding fish could have breast milk DDT/DDE concentrations sufficiently high to expose their infants to levels that could produce deleterious effects.[8]

The purpose of this study was to define, in terms of size and demographics, the infant population exposed in order to assess the magnitude of the problem for local residents. If an exposed population was determined to exist, actual levels of DDT/DDE in breast milk of mothers residing in the Yakima River basin who frequently eat contaminated river fish would have to be obtained, and then determine if the total DDT/DDE levels received by breastfeeding infants were elevated to potentially deleterious levels.

Methods

To determine the population characteristics of infants exposed to DDT through breast milk from mothers consuming contaminated fish, key informant interviews were conducted with community leaders from area farm workers unions, the Yakima County Department of Health pesticide unit, hospital administration staffs, community centers for the Native American, Hispanic and Filipino communities, Maternal and Child Health Services personnel for the Yakima River Valley, and the Department of Fisheries for Yakima County and the Yakama Indian Nation. A series of open-ended questions dealing with recreational fishing patterns of the various communities and social economic strata were asked to gain initial insight into the population characteristics of potentially exposed infants.

Surveys along the riverfront were also conducted over a one-month period. Persons who were fishing on the river were approached and asked questions about their frequency of recreational fishing, which types of fish they caught, and which types of fish they consumed.

Through these preliminary efforts, the most exposed population was identified as the low income Hispanic community. While there was some concern that the Yakama Tribe members might also be exposed to DDT/DDE through fish consumption, Yakama Tribal members view bottom feeding fish as inappropriate for frequent consumption. The following algorithm was developed to determine the minimum size of the population exposed based on characteristics of low income Hispanic women:

(# of infants exposed to elevated levels of DDT/DDE through breast milk)=

(# of Hispanic infants born each year in Yakima County)X

(Proportion of Hispanic families who are low income)X

(Proportion of Hispanic infants who are breastfed)X

(Proportion of Hispanic women who eat river fish frequently)X

(Proportion of Hispanic women who eat river fish who eat contaminated species)

The Washington State birth tapes and Census data were used to estimate the number of infants born each year in Yakima County and the proportion of low income (less than 185% of the federal poverty level) Hispanic families, respectively.[6,9] Women, Infants and Children (WIC) program data for 1994 provided by the Washington State Department of Health were used to calculate a population-weighted breastfeeding rate for Hispanic women attending the three primary WIC clinics in the Valley.[10] Fish consumption patterns of breastfeeding Hispanic women were described through surveys administered at these three primary sites plus two other WIC sites in the Valley. WIC certifiers administered fish consumption surveys addressing frequency, type of fish consumed, and years consuming river fish to random samples of pregnant or breastfeeding clients over a four-month period. Frequent fish consumption was defined as the rate that would subject infants to DDT/DDE breast milk levels at or near the tolerable daily intake.[8] The rate is ≥ 1 meal/wk year-round or ≥ 2 meals/wk during summer months. Fourteen percent of the Hispanic women met this requirement.

Results

A total of 140 surveys were administered to WIC participants attending five WIC sites throughout the Yakima River valley over a four-month period. Greater than 80% of the sample surveyed (N= 114) was of Hispanic origin (Table 1), and 54.4% of Hispanics surveyed were breastfeeding currently, or had previously breastfed (data not shown). Hispanics reported an average residency of 7.1 years in the Yakima River valley, with half of the Hispanic sample living four years or more in the area. In contrast, the Non-Hispanic population reported a mean residency of 16.7 years, with half of the sample reporting 18 years or more residency (data not shown). The mean residence time for Hispanics was significantly lower than for Non-Hispanics ($p < 0.001$).[11]

Fish consumption patterns were determined for both the Hispanic and Non-Hispanic population (Table 1). Hispanics were more likely to report fishing and eating river fish than non-Hispanics. Nearly 9% of Hispanic women reported eating river fish at least once per week throughout the year.

Summer consumption was much higher, with 31.6% of Hispanic women eating river fish at least once per week. Among the Hispanics who ate river fish, 47.5% reported eating species contaminated with DDT, with an additional 28.8% of Hispanics unsure about the types of fish consumed.

Discussion

Each year at least 24 infants from the Yakima Valley may be exposed to levels of DDT/DDE above the tolerable daily intake through breast milk due to their mothers' frequent consumption of contaminated fish (Table 2). Our figure is an underestimate of the true population exposed because the calculated figure was determined using fish consumption patterns and demographic information of only the most exposed group: low-income Hispanics. Undoubtedly, some proportion of women outside this population consume river fish. Also, this annual estimate of exposed infants does not consider growth in future infant population size. Due to the persistence of DDT in the environment, hundreds of infants could be exposed to deleterious levels of DDT in the coming years. As a result, an investigation into the DDT/DDE breast milk levels of these women is warranted to determine if infants are exposed to deleterious levels of these compounds.

We have described a method to determine whether an established environmental concern could impact the health of infants of mothers who frequently consume river fish. This study provided an example of successful community networking and innovative identification of a hard-to-reach population. Our conclusions show that preliminary, low-budget assessment endeavors are vital to health departments for the purpose of project prioritization and resource allocation.

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TABLE 1- Characteristics of Total, Hispanic and Non-Hispanic

Study Population: Survey of WIC Sites

	Total (N= 140) N (%)	**Hispanic** (N= 114) N (%)	**Non-Hispanic** (N= 23) N (%)
Ethnicity			
Hispanic	114 (81.4)		
Non-Hispanic	23 (16.4)		
Unknown	3 (2.2)		
Households Who Fish	55 (39.3)	47 (41.2)	6 (26.1)
Frequency Eating River Fish			
None	74 (52.9)	55 (48.2)	16 (69.6)
Anytime	66 (47.1)	59 (51.8)	7 (30.4)
<1/month	32 (22.9)	27 (23.7)	5 (21.8)
<1/week	21 (15.0)	20 (17.5)	1 (4.3)
1-2/week	8 (5.7)	7 (6.2)	1 (4.3)
3+ times/week	3 (2.1)	3 (2.6)	0 (0.0)
Unknown	2 (1.4)	2 (1.8)	0 (0.0)
Summer Consumption			
None	74 (52.9)	55 (48.2)	16 (69.6)
Any	66 (47.1)	59 (51.8)	7 (30.4)
<1/month	25 (17.9)	21 (18.4)	4 (17.4)
1/week	24 (17.1)	21 (18.4)	3 (13.0)
2/week	10 (7.1)	10 (8.8)	0 (0.0)
3/week	5 (3.6)	5 (4.4)	0 (0.0)
Unknown	2 (1.4)	2 (1.8)	0 (0.0)
Eat Contaminated River Fish[†]			
Yes	32 (48.5)	28 (47.5)	4 (57.1)
No	17 (25.8)	14 (23.7)	3 (42.9)
Unknown	17 (25.8)	17 (28.8)	0 (0.0)

[†] These values represent the number and proportion of women eating DDT-contaminated species (sucker, whitefish, catfish, carp or bass) from those that eat river fish anytime.

TABLE 2 - An Estimate of the Minimum Number of Infants Exposed to High Levels of DDT/DDE Through Breast Milk, Each Year.

Formula Element	Number or Proportion	Data Source
# Hispanic infants born in Yakima Co./Year	1914	Wa. State Birth Tapes, 1991
% Hispanic families low income	40.4	Census of Population, 1992
% Hispanic infants breast fed	46.0	WA WIC Report, 1994
% Hispanic women eating river fish frequently, i.e. $\geq$ 1/wk year-round or $\geq$ 2/wk during summer months	14.0	Table 1 & See Methods
% Hispanic women eating contaminated species	47.5	Table 1

Total Number of Infants Exposed Each Year = 1914 X 0.404 X 0.46 X 0.14 x 0.475 = 24

APPENDIX C

The Effect of Fish Consumption on DDT and DDE Levels in Breast Milk Among Hispanic Immigrants

The Effect of Fish Consumption on DDT and DDE Levels in Breast Milk Among Hispanic Immigrants

ABSTRACT

A study was conducted to 1) determine the concentration of DDT/DDE in the breast milk of mothers residing in the Yakima river basin (WA, USA), 2) assess the relative impact of fish consumption on the total DDT/DDE body burden, and 3) determine if the amount of DDT/DDE received by their breastfed infants exceeds levels that could produce deleterious effects. Results indicate that fish consumption did not significantly increase DDT/DDE breast milk concentrations. Subjects born in Mexico had elevated levels of DDT/DDE in breast milk compared to levels found in US born subjects regardless of fish consumption. Infant daily intake for the various subject groups were determined and compared to acceptable and tolerable daily intake levels . With benefits of breast milk well understood, breastfeeding should still be strongly recommended.

INTRODUCTION

1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane (DDT) and its metabolite 1,1-dichloro-2,2-bis(p-chlorophenyl)-ethylene (DDE) are lipophilic organochlorine environmental contaminants which accumulate in fatty tissue. Breastfeeding infants are exposed to these compounds when lipid is mobilized from maternal fat depots to produce milk. DDT levels in individuals reflect recent exposure to the compound while DDE levels reflect cumulative exposure to DDT and DDE. Although use of DDT has been banned, restricted or phased out in many countries, the long half-life and thus persistence in the environment of DDT and DDE has resulted in continued detection of these compounds in the breast milk of women throughout the world. For example, results from a recent study in New Zealand, where DDT use was phased out during the 1970's, indicated that breast milk from women still contained elevated levels of DDT and DDE.[1] Little is known about short-term effects of DDT and DDE on children, or the effect, in later life, of neonatal exposure to these compounds. The most significant work has involved teratological studies using low doses of DDT in which exposure has been associated with developmental and neurological impairment in neonatal mice.[2-6]

The Yakima river basin of eastern Washington State, USA is a major production site for fruits, vegetables and hops. The Yakima river has been an indispensable water source for irrigation of the naturally arid lands of eastern Washington. Yakima county is ethnically diverse, with 24.4% of the population classifying themselves as Hispanic and 4% as Native American.[7] Prior to its ban in 1972, DDT was sprayed throughout the area for decades, due to its effectiveness as an insecticide.

Between 1989 and 1991, the United States Geological Survey (USGS) collected sediment and fish samples from the Yakima river basin.[8] Large-scale sucker and mountain whitefish were found to have DDT and DDE levels among the highest recorded in the United States (US).[8] Prior research in Sweden has shown associations between contaminated fish consumption and elevated blood plasma levels of DDT and DDE.[9] Analysis of the USGS fish contamination data indicated that mothers who frequently consume Yakima river bottom-feeding fish (large-scale sucker, mountain whitefish, carp, or catfish), could have breast milk DDT and DDE concentrations sufficiently high enough to expose their infants to levels that could produce deleterious effects.[10] These results led to preliminary surveys in the Yakima river basin which indicated that low-income, first generation Hispanics from Mexico formed the population with the highest consumption of Yakima river fish. Results from one survey suggested that of 101 Hispanic women who could identify the fish species they consumed, and were participating in the Women, Infant and Children (WIC) program, 7.4% ate DDT-contaminated fish at least once per week throughout the year. Results also indicated that 24.7% of the 101 women consumed fish at least once per week during the summer months.

This study was conducted to determine actual levels of DDT and DDE in breast milk of lactating mothers residing in the Yakima river basin who frequently eat contaminated river fish, and to determine if the amount of DDT and DDE received by their breastfeeding infants are potentially deleterious.

METHODS

Subject Selection and Sample Protocol

An exposed subject was defined as any woman who ate at least one DDT-contaminated fish meal per week, and was breastfeeding an infant. Unexposed subjects ate no or negligible amounts of contaminated fish from the Yakima river. Previous researchers have noted that background levels of DDT and DDE are often higher in persons who are living in, or have lived in, developing countries as compared to levels among native-born populations in developed countries.[11-13] For this reason, we stratified unexposed subjects by country of origin; native-born (US) and Mexico-born. Each exposed subject was matched to one US-born and one Mexico-born unexposed subject on parity, number of children breastfed and current duration of breastfeeding, resulting in 12 exposed subjects, 12 US-born unexposed subjects and 12 Mexico-born unexposed subjects. Of the exposed subjects, all were born in Mexico with the exception of one US-born woman who was the daughter of an exposed subject.

Recruitment of exposed and unexposed subjects was accomplished through cooperation of area WIC clinics and through fish consumption screening activities of Maternal and Child Health outreach workers who worked throughout the Yakima river basin. All subjects had resided in the Yakima Valley for at least one year. All but one subject invited to participate agreed to be included in the study. All subjects were read a consent form and were administered a questionnaire in English or Spanish that dealt with demographics, reproductive history, breastfeeding habits, occupational history outside of the US (including husband's occupational history), and residential history outside of the US (agricultural or non-agricultural residence). Extent of exposure to DDT/DDE in fish was assessed through questions dealing with number of fish filets consumed per meal, frequency of fish meals per week, species of fish consumed, fish preparation techniques, and time period during which the subject resided in Yakima county and ate river fish. The subject then provided a breast milk sample by complete emptying of one breast (50-100 ml) using a Lactina electric breast pump provided by Medela Inc., McHenry IL. Samples were chilled on ice immediately after collection and were frozen within twenty-four hours.

Laboratory Procedures

Each breast milk sample from the three populations was analyzed for DDT and DDE . This was accomplished by isolating the non-polar lipid fraction using dichloro-methane, and chemically analyzing it for DDE and DDT. Percent non-polar lipid for each sample was obtained so as to determine DDT and DDE levels on a per gram lipid basis which provides a more appropriate method for comparing contaminant levels between samples and subject groups.

A modified version of EPA-600/8-80-038 protocol[14] was followed. A summary, with modifications, of the extraction procedure, pesticide analysis, quality assurance/quality control (QA/QC) and lipids determinations follows.

Extraction Procedure. Frozen breast milk samples were thawed and 50 gm of sample was spiked with surrogates and placed in a sonic bath for 20 min. Samples were then extracted with two volumes of dichloro-methane using a shakeout procedure. The extraction was repeated twice and followed by filtration through sodium sulfate. The extract was then concentrated on a steam bath to 5 ml (approximately) and then brought to 10 ml with dichloro-methane. A 5 ml aliquot was used for lipids determinations. The remaining 5 ml was filtered through a 0.45 μ filter, diluted to 8 ml with dichloro-methane, cleaned by gel permeation chromatography, concentrated, solvent exchanged to hexane and concentrated to a final volume of 0.5 ml which was submitted for pesticide analysis.

Pesticide Analysis. The extracts were analyzed by a gas chromatograph/electron capture/ion trap detector (GC/ECD/ITD). The GC used two fused silica capillary columns for analyte separation. One column was connected to the ITD and one to the ECD. A single extract injection was split internally in the GC and was analyzed by the two columns concomitantly. A 5 point and a 3 point external calibration curve was used to quantify the ECD and ITD data, respectively. DDT and DDE were identified by their elution times and spectrums relative to known standards. Extracts with values above the highest point on the calibration curve were diluted and analyzed again.

Lipids Determinations. A 5 ml aliquot retained from the extraction process was allowed to evaporate. The quantity was reweighed and lipids were determined gravimetrically.

QA/QC. The surrogates used to spike the samples prior to extraction were tetrachloroxylene and decachlorobiphenyl. Only two samples were analyzed in duplicate due to the volume required to analyze each sample. Prior to pesticide analysis, an extract spiking detection limit study was completed for the breast milk samples. To establish general detection limits, two extracts were spiked with two levels of DDT and DDE standards and analyzed. To ensure consistency of the laboratory results, the analysis was performed by the same individual, and all samples went through the extraction process and pesticide analysis sequentially to minimize variation.

Data Analysis

Natural log transformations of DDT and DDE data were necessary due to their non-normal distributions. These transformed variables were normally distributed and were used in all analyses. Analysis of variance (ANOVA) was used to compare mean values of demographic characteristics and DDT/DDE levels of exposed subjects with US-born and Mexico-born unexposed subjects. Subjects with breast milk DDT or DDE levels below the detection level were assigned half the detection level (0.13 μg/kg). This was used as a DDE value in two US-born unexposed subjects, and as a DDT value in three exposed subjects, eight US-born unexposed subjects, and five Mexico-born unexposed subjects.

Infant intake levels of DDE/DDT were determined using median DDE and DDT levels in breast milk lipid, a milk lipid level of 3.5%,[15] an infant daily intake of 0.85 kg breast milk,[16] and an infant body weight of 5 kg (50th percentile for a 2-month-old baby).[17]

RESULTS

The subjects were matched on parity (3.0 ± 2.2), number of children breastfed (1.7 ± 2.3) and current duration of breastfeeding (in months, 4.0 ± 4.6). The exposed subjects in this study ate an average of 3.9 (± 2.3) contaminated fish fillets per week (large-scale sucker, mountain whitefish, carp, catfish or bass), compared to 0.02 (± 0.0) fish fillets per week in the unexposed groups ($p<0.05$).

Table 1 compares demographic characteristics of exposed and unexposed subjects. Groups were similar for characteristics examined with the exception of education. The mean educational level for exposed subjects (7.5 years) was significantly different from the mean educational level for US-born unexposed subjects (12.8 years, $p<0.01$).

Table 2 presents the medians and ranges of DDT and DDE levels in lipid for exposed and unexposed subjects. Mean lipid levels of DDE and DDT were highest for Mexico-born unexposed subjects, however these did not differ significantly from the mean levels of the exposed subjects.

Mean lipid concentrations of the breast milk samples were not significantly different between groups. For exposed subjects, US-born unexposed subjects, and Mexico-born unexposed subjects the mean amounts of non-polar lipid extracted were 0.64 (± 0.5), 0.86 (± 1.3) and 1.20 (± 1.7) g/100 ml breast milk, respectively.

The estimated median infant daily intakes for exposed subjects, US-born unexposed subjects, and Mexico-born unexposed subjects were 5.0×10^{-3}, 1.4×10^{-3} and 12.4×10^{-3} mg/kg/day, respectively. Three Mexico-born subjects, one from the exposed group and two from the unexposed group, had intake levels equal to or greater than 50.0×10^{-3} mg/kg/day.

DISCUSSION

Fish Consumption, Hispanic Immigrants and DDT/DDE Breast Milk Levels

This study compared breast milk levels of DDT and DDE in women who frequently ate certain types of river fish known to have high levels of the contaminants to women who ate no or negligible amounts of these river fish. The exposed subjects were predominantly low-income Hispanic women who had migrated to the Yakima river valley an average of 7.5 years earlier. Although there were no significant differences in mean lipid concentrations of DDE and DDT between exposed subjects and US-born or Mexico-born unexposed subjects, Mexico-born unexposed subjects had the highest DDE and DDT levels, exposed subjects had intermediate levels and US-born unexposed subjects had the lowest levels. One possible explanation for this finding is the high background levels of DDT and DDE in Mexico-born immigrants, who represented all individuals in the Mexico-born unexposed group, and 11 of 12 individuals in the exposed group. As a result, this study was unable to attribute high DDT or DDE levels in exposed subjects to consumption of fish from the Yakima river. It must be noted, however, that the small sample size for comparison does not completely rule out the possibility that DDT and DDE levels could increase in individuals consuming large amounts of fish.

An additional limitation was the inability to control for the time of sampling and the last feeding on that breast. Time of sampling is important since lipid levels vary throughout the day.[15] An attempt was made to schedule interviews in the afternoon, however, this was not always possible. In this study, time of sample collection (morning versus afternoon) was not found to influence either lipid levels or DDT/DDE levels. The time interval between sample collection and last feeding was not controlled for due to limited access to these individuals. This variable is the most important predictor of fat content; lipid concentration decreases as the interval increases.[15]

The stratification of unexposed subjects by country of origin was justified given the higher DDT and DDE levels among persons from developing countries compared with persons from developed countries.[11-13] The high levels of DDT and DDE observed in Mexico-born immigrants are consistent with results from recent studies indicating that DDT and DDE levels in human adipose tissue and breast milk along with the total DDT body burden of the Mexican population are among the highest of all countries for which data are available.[18-21]

Infant Intake of DDE and DDT

Infant intake levels of DDE/DDT were estimated since high concentrations of DDE/DDT were found in the breast milk of many Mexico-born individuals. A tolerable daily intake (TDI) of 5×10^{-3} mg/kg/day total DDE and DDT has been established for breastfeeding infants.[10] This TDI, which is based on sensitive endpoints in human and animal populations, is very similar in value to the acceptable daily intake (ADI) of 20×10^{-3} mg/kg/day previously developed by FAO/WHO in 1985.[22] Both values estimate an intake level that would not produce any deleterious effects. Median infant daily intake for exposed subjects and US-born unexposed subjects were at or below the TDI and ADI while the median infant daily intake for Mexico-born unexposed subjects was 2.5 times greater than the TDI but less than the ADI. Three Mexico-born subjects had infant daily intake levels well above both values.

Although human breast milk contains DDT and DDE, breastfeeding should still be strongly recommended since the many nutritional, immunological, and physiological benefits to the infant from nursing, outweigh the possible negative effects from DDT and DDE exposure through breastfeeding at most concentrations presently observed. However, the elevated levels in breast milk observed in the Mexico-born immigrants does raise concerns about this population in the US. The possibility that DDT/DDE may cause health effects in infants at these exposure levels strengthens the need for critical evaluation of the scientific bases of these conclusions. Also, any population potentially affected through DDE/DDT exposure should be monitored to ensure that infant exposure levels do not greatly exceed the daily intake levels deemed to cause no deleterious effect, and that levels decrease as exposure is removed. While further research results are forthcoming, lactation clinics and programs such as WIC and Maternal and Child Health outreach can be a primary source for public health intervention by providing education and information on the benefits of breastfeeding, and the possible health consequences that could occur from overexposure to compounds like DDT and DDE. By coordinating efforts with these programs, populations of greatest concern can be reached and educated in regard to improved dietary practices and the benefits of breastfeeding.

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Table 1. Mean values for exposed subjects and unexposed subjects by birthplace.

	All Exposed Subjects (n=12) Mean (sd†)	US-born Unexposed Subjects (n=12) Mean (sd)	Mexico-born Unexposed Subjects (n=12) Mean (sd)
Age	26.3 (5.9)	27.7 (6.6)	28.4 (5.1)
Years in Mexico	17.8 (6.7)	0 (0.0)	20.3 (5.9)
Years in US	8.5 (5.6)	27.7 (6.6)	8.2 (5.8)
Years in Yakima Co.	7.5 (5.0)	15.5 (12.3)	4.2 (3.8)
Yrs. agro. work in Mexico	1.2 (2.4)	0 (0.0)	0.8 (2.0)
Total months breastfeeding	12.1 (9.7)	10.8 (9.3)	17.7 (17.1)
Months since last child was breastfed	24.4 (24.6)	15.7 (21.6)	33.1 (36.2)
Education (y)	7.5 (3.5)	12.8 (3.3)*	7.2 (3.6)

† Standard deviation

* The mean difference between exposed subjects and US-born unexposed subjects for this variable was significant (p<0.01).

Table 2. Median and ranges of DDT and DDE values (μg/kg) in breast milk and lipid for exposed subjects and unexposed subjects by birthplace.

	Exposed Subjects (n=12)	US-born Unexposed Subjects (n=12)	Mexico-born Unexposed Subjects (n=12)
	Median (Range)	Median (Range)	Median (Range)
DDE (μg/kg lipid)	827.5 (280-7200)	165 (45-1260)	1913.5 (149-11545)
DDT (μg/kg lipid)	34.7 (0.13-1090)	37.9 (10-130)	148.5 (21.7-3636)
Σ(DDT + DDE) (μg/kg lipid)	836 (290-8290)	229 (72-1303)	2077 (203-15181)